AIR FORCE OFFICE of SCIENTIFIC RESEARCH [AFOSR]
Manager of the Basic Research Investment for the Air Force

Research HIGHLIGHTS

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Five Decades of Research that Helped Change the World

AFOSR at 50:

The laser. Precision Munitions. The Computer Mouse. Stealth Aircraft. These are but a few pioneering innovations produced by scientists funded by the Air Force Office of Scientific Research since it opened its doors 50 years ago.

Born out of a need to address a long-standing shortfall in military basic research, particularly during the World War II years when weapons development was the sole province of civilian-led research efforts, AFOSR has a proud history of developing revolutionary scientific ideas that have directly benefited the Air Force and mankind.

"Innovation," observed Dr. Lyle H. Schwartz, AFOSR director, "will continue to be a key ingredient for Air Force mission success. Whether it be in access or use of space, in rapidly reaching the geographic regions of interest in identifying a potential target, or in defense against a threat to our nation, technological superiority will be our winning strategy."

Part of that strategy has meant teaming the best researchers in academia, industry, federal agencies and the Air Force Research Laboratory to develop a wide array of technologies that are in use today. That strategy also has contributed to 43 Nobel laureates.

Here, by decade, are some of the important breakthroughs made possible by AFOSR.

The 1950s

Dr. Charles Townes conceived the idea of the MASER (Microwave Amplification by Stimulated Emission of Radiation) in 1951 and demonstrated the same in 1954.

In early 1957, an AFOSR program manager approached Townes to suggest undertaking work on the existing idea of generating coherent radiation at optical frequencies. Along with Dr. Art Schawlow, Townes published the principles of the laser in 1958, and for his maser/laser work, shared the Nobel Prize in physics in 1964 (Schawlow would win the Nobel Prize for his contribution in 1981). Its applications have been used in everything from communication and the Airborne Laser (ABL), to eye surgery and topography mapping.

In the late 1950s, AFOSR research contract supported the work of Dr. Rudolph Kalman and Dr. Richard Bucy to investigate the use of modern mathematical statistical methods in estimation. It led to the development of the Kalman Filter, which became a basic building block of flight. Almost all modern control systems — both military and commercial, as well as Global Positioning Satellite technology — use the Kalman Filter. It guided the Apollo 11 lunar module to the moon's surface and will guide the F-22.

AFOSR was a pioneer in the theoretical and application work associated with the integrated circuit. In 1958 and 1959, two Air Force scientists working at Wright Field secured AFOSR funding for Dr. Jack Kilby to work on integrated circuits. AFOSR was an early supporter and advocate for the application of semiconductor development for potential use in Air Force weapons systems. Kilby, who won the Noble Prize for physics in 2000 for his invention, noted that early ballistic missile tests with integrated circuits largely assured the acceptance of semiconductor technology for other military and commercial uses.

The 1960s

In the early 1960s, AFOSR awarded a contract for research on augmenting human intellect and the potential of computers to assist people in complex decision-making. The report, published in 1962, served as a

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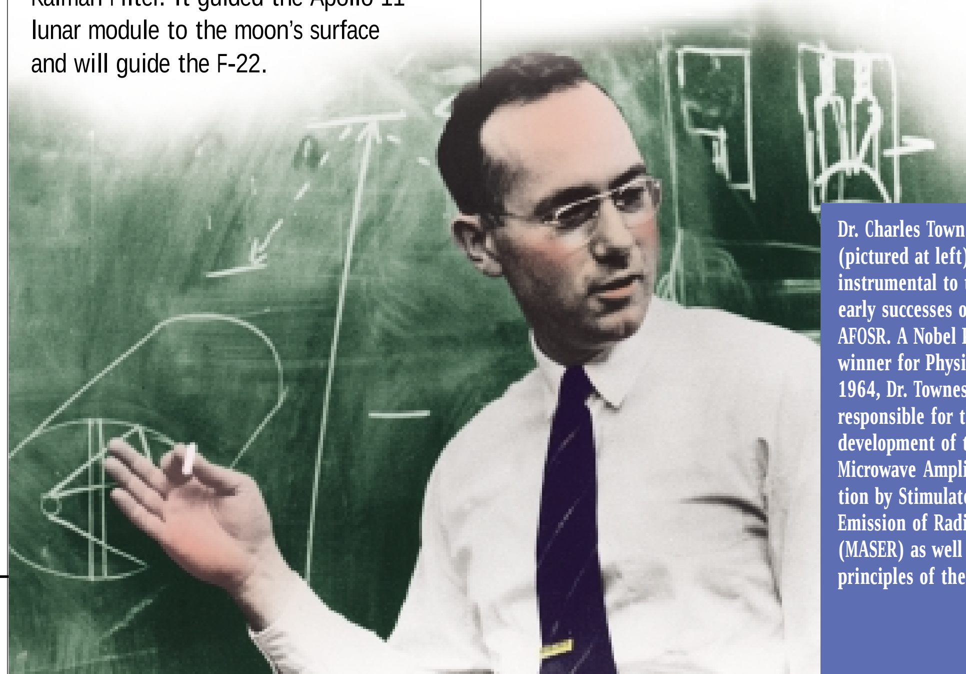

Dr. Charles Townes (pictured at left) was instrumental to the early successes of AFOSR. A Nobel Prize winner for Physics in 1964, Dr. Townes was responsible for the development of the Microwave Amplification by Stimulated Emission of Radiation (MASER) as well as the principles of the laser.

AFOSR at 50:

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road map for developing computer technologies. This was followed in 1964 by the same researcher with the introduction of the first computer mouse, which was part of an experiment to find better ways to "point and click" on a display screen. With early funding for the inventor of the mouse and scores of computer-related innovations, AFOSR was in on the ground floor in support of the computer revolution.

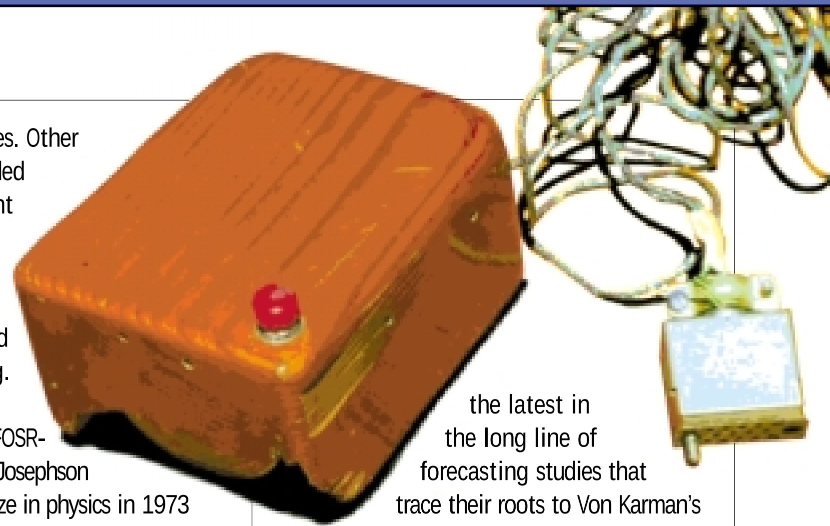
Another common technology of today was also taking shape at this time with the help of AFOSR research. While operating under an AFOSR grant in 1967, a design was conceptualized for a low cost Global Positioning System. It has become indispensable as a tool in targeting, reconnaissance, and search and rescues.

Several years after the Kalman Filter algorithm was making its way into practical application, a revolutionary digital decoding algorithm was discovered by Dr. Andrew J. Viterbi while doing research support for AFOSR. By the mid-1970s, Viterbi's algorithm was rapidly becoming the standard method for decoding in space communication systems. NASA employed this algorithm with great success in the Voyager flight to Jupiter and Saturn. It has been widely used in other military and civilian space programs including MILSTAR, DSCS, the Shuttle program and various commercial satellites.

A digital decoding algorithm discovered by AFOSR-funded Dr. Andrew J. Viterbi helped make the Voyager mission a success on its flight to Jupiter and Saturn.

The 1970s

This decade saw AFOSR increased program emphasis on a number of areas that ultimately produced significant results in future Air Force systems. These included cross-disciplinary research in nondestructive evaluation of structural and electronic materials. AFOSR-funded scientists investigated the phenomena of fatigue and fracture in aerospace systems that yielded high payoff in engineering design to increase the longevity of aircraft structures and engines. Other research areas included the study of turbulent friction on aircraft, particularly transports, pulsed power, micro-fabrication and software engineering.



In the area of superconductivity, AFOSR-supported Dr. Brian Josephson received the Nobel Prize in physics in 1973 for developing what became at that time, the world's most sensitive magnetometers and the fastest, lowest power switching elements, leading to a new generation of computers.

The 1980s

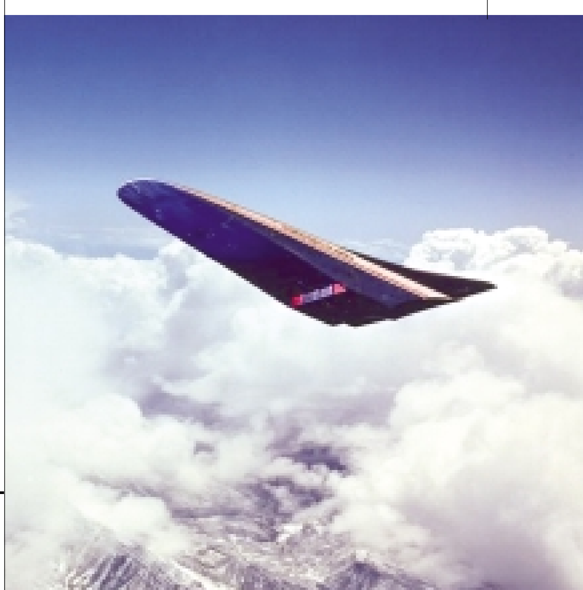
Five areas received a major increase in emphasis starting in the early 1980s. Two of these areas, Directed Energy Physics and Space Systems Science were concerned with the stimulation of new concepts in emerging technological areas. Two other areas, Weapon System Automation and Command and Control Science, were concerned with related aspects of future weapons systems in which technology either displaced or greatly augmented human capabilities. The fifth area sought to explore technologies that would be required to support continued tactical systems operations during the next decade when aviation fuel was projected to become increasingly scarce.

In March 1983, President Reagan announced the Strategic Defense Initiative (SDI) program. AFOSR had to address this issue by an expanded research effort in the areas critical to SDI including sensors, lasers, space propulsion, ultra high-speed computing, and advanced space materials. Two years prior to the SDI program, the Air Force initiated Project Forecast II (PF II), the latest in the long line of forecasting studies that trace their roots to Von Karman's report of the Scientific Advisory Group in 1944. Begun in August 1985, PF II was a six-month study to identify potential 21st century technologies and weapon system concepts. Attention was focused in critical areas and AFOSR played a key role in shaping that focus, especially regarding the emphasis on high energy density propellants, which paid significant dividends in the next decade.

The 1990s

In 1991, when AFOSR marked its 40th anniversary, it was obvious that AFOSR had fulfilled its long-term mission as many of the benefits of AFOSR-sponsored basic research had been successfully fielded and employed in daily operational use during the Persian Gulf conflict. AFOSR initiatives contributed significantly in the areas of guidance and navigation systems, stealth, surveillance, communications, and targeting.

Several AFOSR key breakthroughs in the latter half of the 1990s dealt with the successful biodegradation of hazardous rocket fuel waste, the hyper-mixing of fuel/air in scramjets (National Aerospace



The first mouse was invented in 1963-64 as part of an experiment to find better ways to "point and click" on a display screen. Due to space restrictions, the first mouse (pictured at left) had only one button and was carved out of wood. An "upgraded" mouse with three buttons was eventually designed, but the extent of its improvement was limited by the space required for the three micro-switches.

Plane), infrared video camera advancements, laser trapping and cooling, the miniaturization of space vehicles (Techsat-21), space weather, self-healing plastics, Dip-Pen Nanolithography, enhanced propellants (polynitrogen), and biomimetics.

Poised at the beginning of the new millennium, AFOSR continues to successfully perform the mission it was given 50 years ago: to focus the scientific community on Air Force requirements, to research foundation technologies for critical Air Force systems and to forge transitions of innovative technologies. In so doing, AFOSR will continue to fortify its reputation as a world class organization through early and accurate selection of premier research scientists and programs that will support the Air Force warfighter of tomorrow.

"The AFOSR team is proud of the important mission it performs," Schwartz said. "Basic research creates new knowledge. It is this new knowledge that leads to revolutionary new capabilities."

Join Us as AFOSR Celebrates Its 50th Anniversary

To commemorate five decades of basic research, AFOSR will mark the milestone with a 50th Anniversary Celebration that includes a conference, exhibits, poster session and luncheon on April 25, 2002 at the Ronald Reagan and International Trade Center in Washington, D.C. For more information about the events or to receive your conference mailer (shown above), contact AFOSR at (703) 588-0673 or: **www.afosr.af.mil**

Be sure to act now...space at all events is limited!

AFOSR-funded research has helped propel the U.S. space program to new heights with advances in the areas of biodegradation of hazardous rocket fuel waste and the hyper-mixing of fuel and air —important technologies that will be needed in order to make the National Aerospace Plane (illustrated at left) a reality. Photo-illustration compliments of NASA.

New Advances in Mid-infrared Lasers

New sources for mid-infrared semi-conductor lasers are being developed to monitor the environment and detect chemicals are being developed by Air Force Office of Scientific Research's (AFOSR) principle investigator, Dr. Jason Chi at the University of Oklahoma (UO).

Future payoffs for the Air Force may result in being able to detect manufacturing plants for chemical weapons, testing and detonation of chemical weapons, detecting vehicle fumes to monitor movement and infrared countermeasures.

Along with the research at UO, AFOSR is funding concurrent studies at the Air Force Research Laboratory at Kirtland, AFB in New Mexico focusing on antimonides using lead-salt semiconductors. Antimonides are dopants put into semiconductors to enhance lasing.

For mid-infrared lasers, the types of platforms on which it can be used are limited by operating temperatures. Lead-salts were selected, because they have:

- a higher rate of success in reaching proper temperature to be usable for the mid-infrared laser platform;
- the lowest coefficients of any semi-conductor in this wavelength range;
- and, a much lower non-radiative recombination rate.

In lasers, it is desirable to have each electron create a photon of light as it transitions to a lower energy state. One problem plaguing antimonide-based lasers is the transmission of energy from one electron to another with no release of photons.

Also, lasers can be either optically or electrically pumped. Optical pumping involves photons in the laser medium being absorbed, exciting species to higher energy states. In electrical pumping this excitation is the result of either direct effects or collisions. For mid-infrared semiconductor lasers optical pumping is preferred because it is easier to fine-tune the excitation.

FIGURE 1

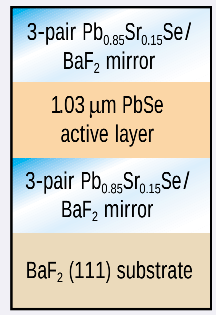
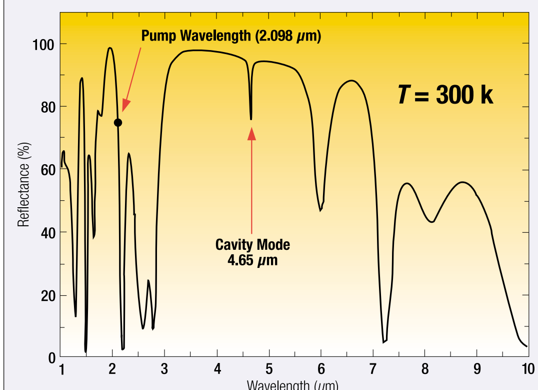


FIGURE 1 (left): Lead-salt vertical cavity surface emitting laser structure for operations at 4μm.

FIGURE 2 (below): Spectral response of the laser's resonant cavity shows the cavity mode at 4.65 μm at room temperature

FIGURE 2



Recent advances made in the development of optically pumped lead-salt mid-infrared vertical cavity surface emitting lasers (VCSEL) appear very promising. The most exciting development is the recent demonstration of above-room temperature laser emission.

In the demonstration, optically pumped lead-salt VCSELs using quantum wells operated at above room temperature in a pulsed mode. VCSELs used quantum wells to coax light out of electrons. The quantum wells efficiently collect electrons and provide a path to a lower energy position, the difference in energy given off as light.

Having the gain peak and cavity mode of the VCSEL structure in resonance at 300K, makes these devices very efficient at room temperature and the lasing wavelength stays nearly constant over a large temperature range.

The temperature stability combined with operating at room temperature also minimizes cooling requirements, which reduces the weight and size of a laser.

This ground-breaking work has resulted in the first lead-salt infrared VCSEL and is supported by AFOSR's Physics and Electronics directorate.

Maj. Dan Johnstone, AFOSR/NE

Scientist Receives Silver Cross of Honor of the Federal Armed Forces from the Federal Republic of Germany

The Federal Republic of Germany bestowed one of its highest military honors, the Silver Cross of Honor of the Federal Armed Forces, to a scientist on Thursday, Jan.17, at the German Liaison Office for Defense Materiel in Reston, Va.

Col. T. Jan Cerveny, Ph.D., Director of External Programs and Resources Interface at the Air Force Office of Scientific Research, earned the nomination for her personal commitment and dedication to the Engineer and Scientist Exchange Program (ESEP) between the U.S. and Germany.

Since 1963, the two countries have conducted the ESEP program. To date, more than 1,500 engineers, military officers and civil servants have taken advantage of the opportunity to participate in a one-year scientific or technical assignment in each other's countries.

Under Cerveny's leadership, a memorandum of understanding was orchestrated between the countries allowing administrative officers and personnel with a particular specialization, such as geology and psychology, the ability to participate in the ESEP program.

The Silver Cross of Honor of the Federal Armed Forces is rarely awarded to a non-German and is similar in rank to the U.S. Legion of Merit.

Pictured above, from left to right: Phil Gibber, Joseph Niksic, Brig. Gen. Peter Goebel, Andreas Zekorn, Col. T. Jan Cerveny (wearing the Silver Cross of Honor of the Federal Armed Forces), Ralf Duckerschein, Mark Saueressig, Jochen Handschuch, and 1st Lt. Marco Ruppenthal, and Gary Bernesque

Lakatos Award

Dr. Judea Pearl, Professor of Computer Science and Statistics and Director of the Cognitive Systems Laboratory at the University of California in Los Angeles, received the Lakatos Award 2001 for his book, "Causality: Models, Reasoning and Inference."

Pearl's book focuses on developing causality as a precise, mathematically expressed idea with important applications in the fields of statistics, philosophy of science, cognitive science and health and social sciences. The award is given by the London School of Economics and Political Science for outstanding contribution to the philosophy of science in a book published in English within the previous six years. Pearl is funded by AFOSR's Mathematics and Space Sciences Directorate.

Dr. Judea Pearl

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

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